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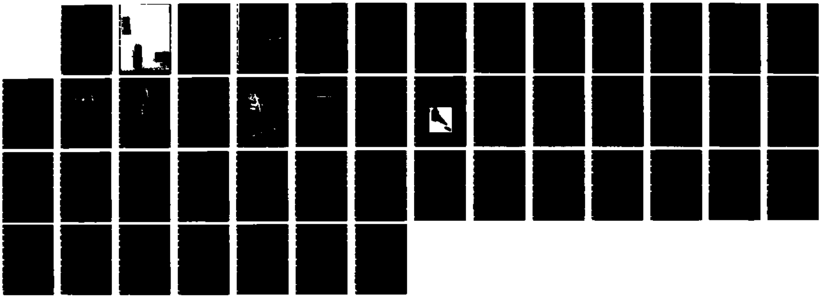

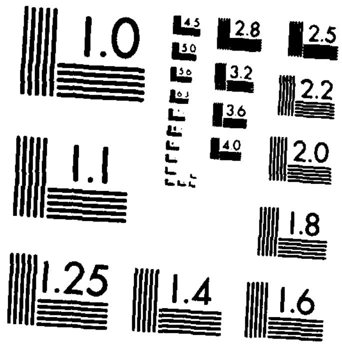
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Studies were conducted from May 1982 to October 1983 to evaluate the effectiveness of nine methods for collecting macroinvertebrates associated with dikes, revetments, and sandbar habitats. Data were collected on the Lower Mississippi River between river miles 440 and 448. The nine methodologies evaluated included circular rock basket implants, rock samples, the push sled, the diaphragm pump, the electroshocker, articulated concrete mattress (ACM) implants, ACM slabs, ACM blocks, and a modified Hess sampler.

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20. ABSTRACT (Continued).

Some gear types were used to test diel variations in the macroinvertebrate communities while others were used to obtain information on community structure and seasonal variation at dike, revetment, and sandbar habitats.

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PREFACE

The study described in this report was sponsored by the Office, Chief of Engineers (OCE), US Army, under the Environmental and Water Quality Operational Studies (EWQOS) Program, Work Unit VII.B, Waterways Field Studies. The EWQOS Program has been assigned to the US Army Engineer Waterways Experiment Station (WES) under the direction of the Environmental Laboratory (EL). The OCE Technical Monitors for EWQOS were Mr. Earl Eiker, Dr. John Bushman, and Mr. James L. Gottesman.

This report presents results of studies designed to evaluate nine methodologies for sampling macroinvertebrates within the main-line levees on the Lower Mississippi River. Habitats investigated were those associated with and affected by dikes and revetments. The studies were conducted from May 1982 to October 1983. The results of these studies plus related experience with macroinvertebrate sampling gear were evaluated during 1985 to provide information on sampling in large rivers in support of technology transfer activities under the Waterways Field Studies Work Unit. Sampling sites were located between river miles 440 and 448.

This report was prepared by Messrs. Larry G. Sanders and C. Rex Bingham and Dr. David C. Beckett, under the supervision of Dr. Thomas D. Wright, Chief, Aquatic Habitat Group; Dr. Conrad J. Kirby, Chief, Environmental Resources Division; and Dr. John Harrison, Chief, EL. Dr. Jerome L. Mahloch was Program Manager of EWQOS. The report was edited by Ms. Jessica S. Ruff of the WES Information Products Division.

COL Allen F. Grum, USA, was the previous Director of WES. COL Dwayne G. Lee, CE, is the present Commander and Director of WES. Dr. Robert W. Whalin is Technical Director.

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CONTENTS

MACROINVERTEBRATE GEAR EVALUATION

PART I: INTRODUCTION

Background

1. From 1978 through 1980, personnel of the US Army Engineer Waterways Experiment Station, Aquatic Habitat Group (AHG), conducted macroinvertebrate surveys on the Lower Mississippi River between river miles 480 and 530. These surveys were part of the Environmental and Water Quality Operational Studies (EWQOS) Program sponsored by the Office, Chief of Engineers, US Army. Macroinvertebrate surveys were conducted as a part of a larger study undertaken by the AHG to evaluate the impacts of channel alignment structures (dikes and revetments) on fishes, macroinvertebrates, and water quality parameters in large river systems.

2. The macroinvertebrate surveys included collections from various habitats over the entire study reach. While samples collected using conventional sampling gear provided valuable information from all habitats sampled, the direct contribution of the dike and revetment structures to the ecological communities in large rivers remained virtually unknown due to sampling difficulty. Because of insufficient data, sampling efforts in this study focused directly on dike and revetment structures and the shallow waters associated with the sandy middle bars.

3. In this study, conducted from May 1982 to October 1983, personnel of the AHG designed new gears and implemented various techniques to evaluate gear performance for collecting macroinvertebrates.

Objectives

4. The basic objective of this study was to evaluate the effectiveness of nine methodologies for sampling macroinvertebrates associated with dikes and revetments. The gears evaluated were circular

rock basket implants, rock samples, the push sled, the diaphragm pump, the electroshocker, articulated concrete mattress (ACM) implants, ACM slabs, ACM blocks, and a modified Hess sampler.

Study Area

5. A reach of the Lower Mississippi River between river miles 440 and 448 was selected for this study. The river is confined on both sides at all sites by main-line levees within the study area. Leveed floodplain width ranged from 3.2 to 9.6 km. Backwater habitats between the levees and the main river channel have indirect or seasonal connections with the river and are submerged during flooding. No tributaries enter the river within the study area. The area is considered to be typical of the Lower Mississippi River upstream of Baton Rouge, La.

6. At Vicksburg, a major gaging and data collection point located at approximately river mile 337.7, the average discharge is about 15,876 m^3/sec. Recorded discharges have ranged from 2,830 m^3/sec at extreme low river stage to 76,410 m^3/sec at extreme high stage, with an 18.7-m difference in water level. The average water velocity within the main channel is from 0.9 to 1.9 m/sec, with a maximum recorded velocity of 4.7 m/sec. The average hydrograph for the river at Vicksburg shows highest discharge occurring from February through March and lowest discharge from July through October.

7. The circular rock basket implants, diaphragm pump, electroshocker, ACM slabs, and ACM implants were tested at the Marshall Cutoff Dikes and Marshall-Browns Point Revetment between river miles 447 and 448 (Figures 1 and 2). The push sled was tested along the sandbar between dikes 1 and 2 and below dike 2 at the Marshall Point Dikes (Figures 1 and 2). Dike 1 was located at approximately river mile 448 (farthest upstream), and dike 2 was located at approximately river mile 447.5. The ACM blocks were tested at three locations--river miles 440, 445, and 447 (Figures 1 and 3). The modified Hess sampler was tested at river mile 447.

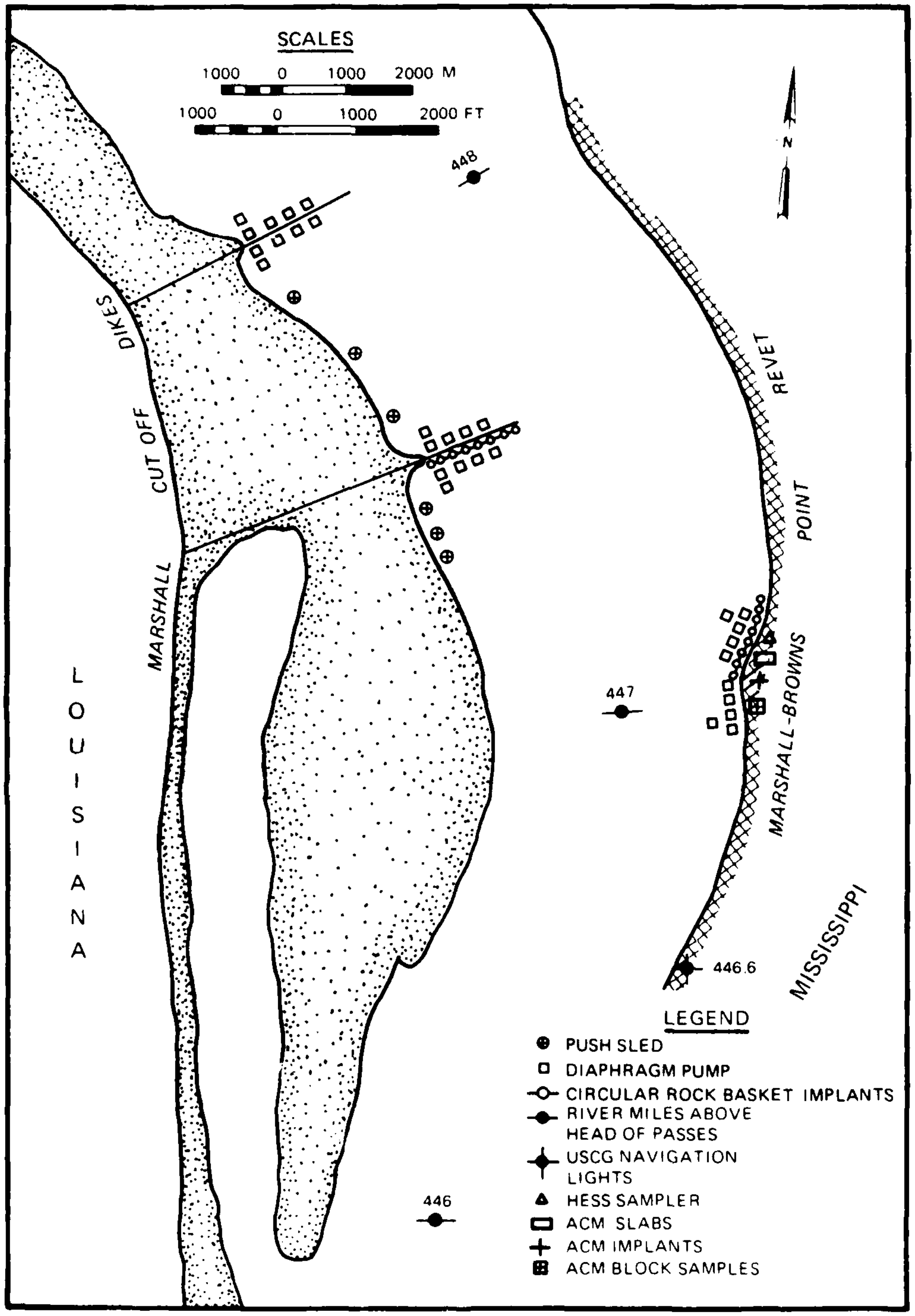


Figure 1. Locations of tests in study area, river miles 446-448

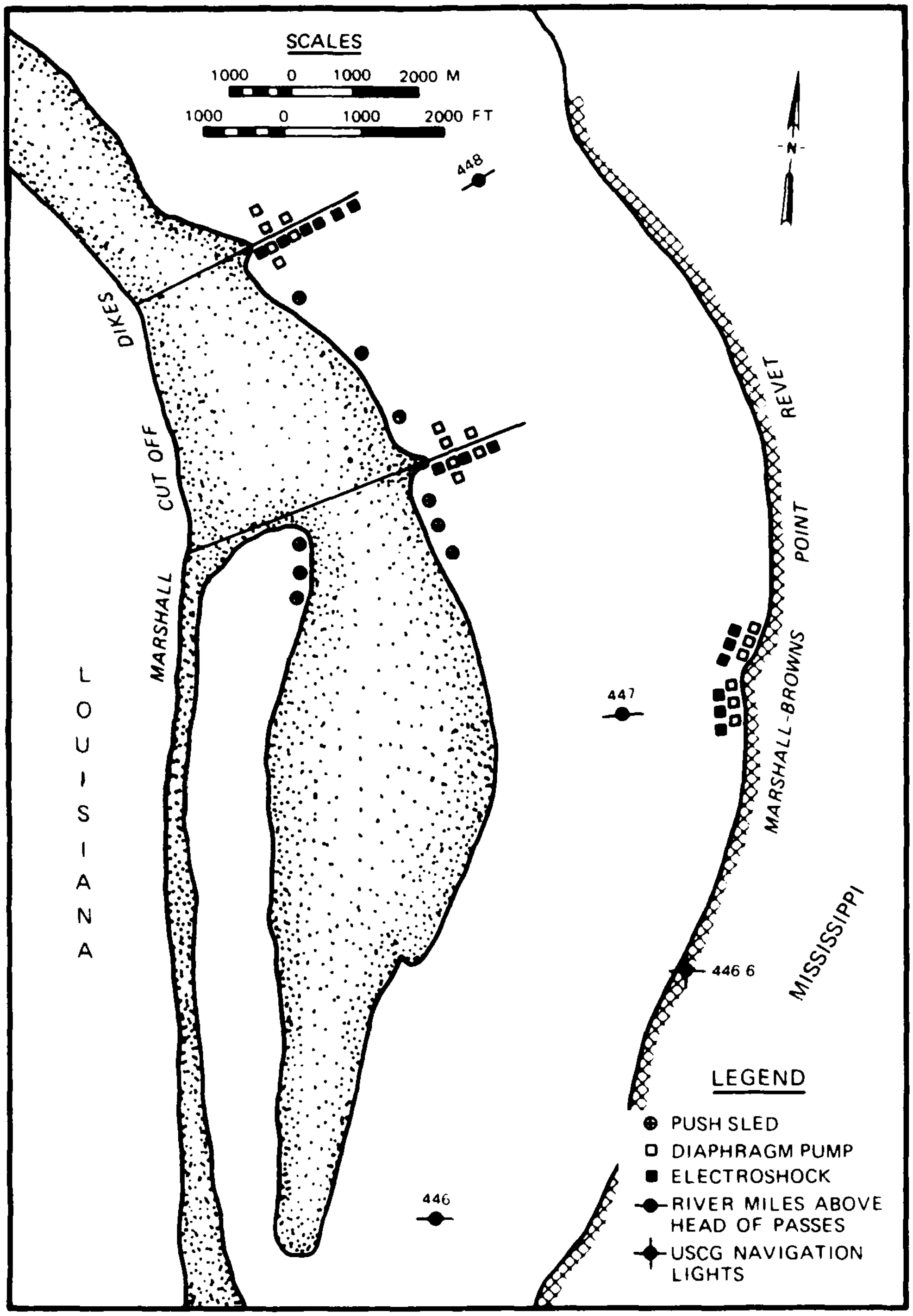


Figure 2. Locations of tests (including electroshocking) in study area, river miles 446-448

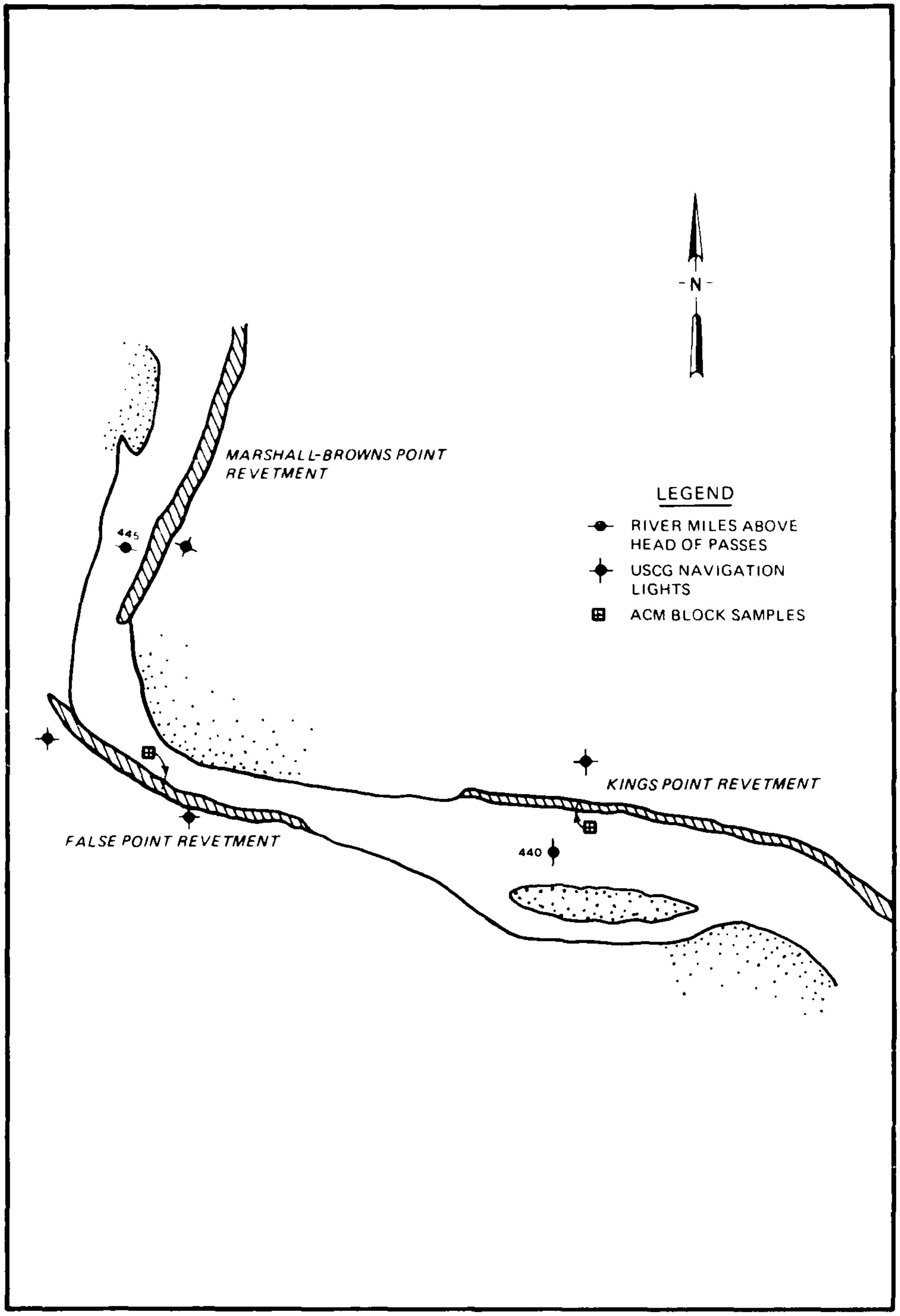


Figure 3. Locations of tests in study area, river miles 440-445

Testing Methods

Circular rock basket implants

8. The implants were constructed in such a manner that one basket (the basket that would hold the rocks) could be mounted inside a larger basket. The larger basket had a diameter of 12 in. (30.4 cm) and a height of 16 in. (40.6 cm); the smaller basket had a diameter of 8 in. (20.3 cm) and was similar in height. A nylon bag (0.505-mm mesh) was placed between the inner and outer basket (Figure 4) and was attached to cables in such a manner that, upon retrieval, the bag would be pulled up around the inner basket containing the rocks. The purpose of the nylon bag was to minimize loss of organisms during retrieval.

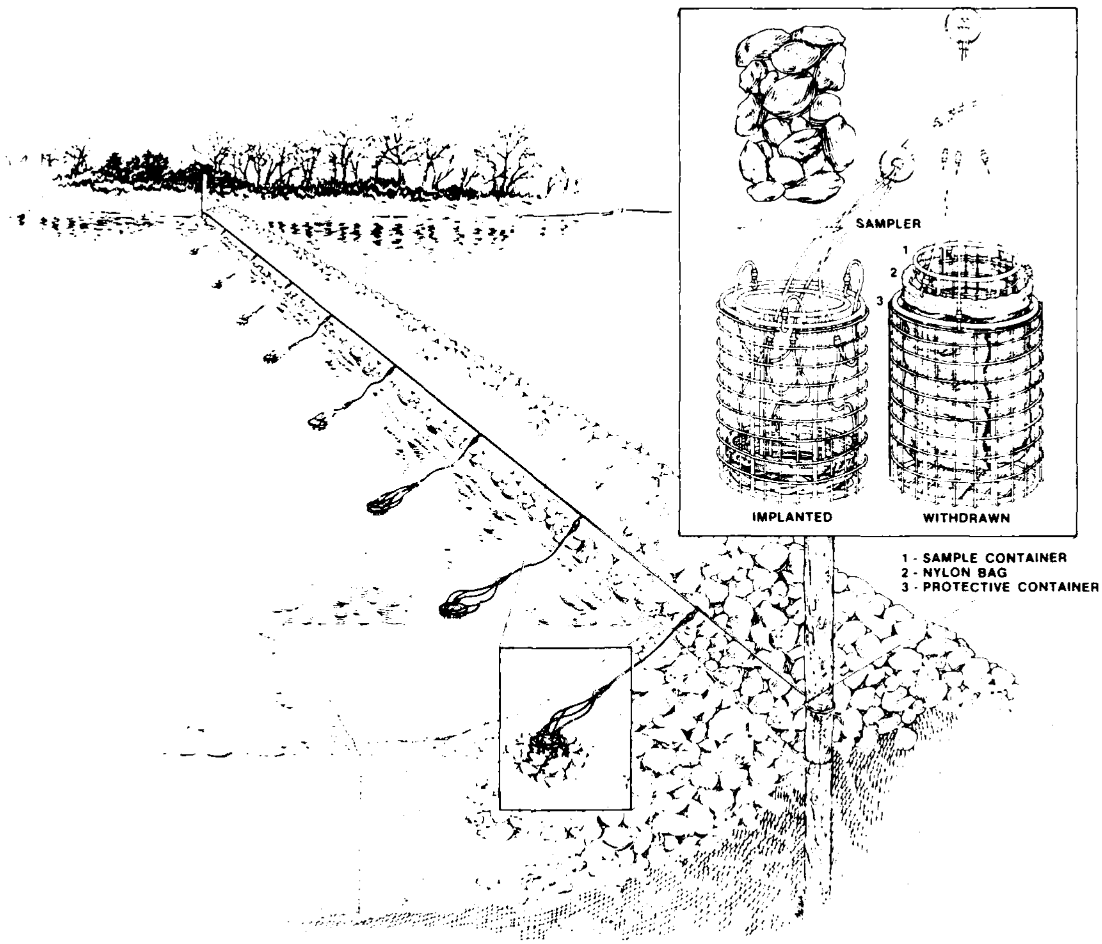


Figure 4. Circular rock basket implants

9. Each basket was buried to a sufficient depth so that the top was flush with the surface of the rocks on the dike or revetted bank. All baskets at a location (dike or revetted bank) were anchored to a length of 0.635-cm-diam aircraft cable. Soon after implanting, the baskets were submerged by rising water levels. The baskets remained inundated from late January through late May, at which time they were retrieved. The entire implant assembly (inner basket with rocks, raised net, and outer basket) was pulled into the boat, using a winch. The contents of the inner basket were dumped into a washtub, material adhering to the net was rinsed into the tub, and a toothbrush was used to scrub material on the rocks into the tub. (The scrubbed rocks were discarded.) Contents of the washtub were then sieved using sieve buckets with a mesh size of 0.505 mm, and the material retained by the sieve was rinsed into a collection jar and preserved in 10-percent buffered formalin.

Rock samples

10. Random stations were selected in July 1982, both upstream and downstream of a dike and along a stretch of revetted bank. From each of these stations a total of three stones (rocks or riprap) were collected by wading to a depth of approximately 0.7 m and retrieving the stones by hand. Upon retrieval the stones were placed in a plastic bucket, taken to the shore, and thoroughly scrubbed. The sample was placed in a container and fixed with 10-percent buffered formalin.

Push sled

11. A push sled (Figure 5) was constructed using aluminum. The sled was mounted on four rubber wheels and had a rectangular plankton net (mouth = 0.455 × 0.305 m) attached at the front. The mesh size of the plankton net used was 0.505 mm. Macroinvertebrates collected with the sled were obtained from several 30-m-long transects parallel to a sandbar shoreline. Samples were obtained during day and night in shallow water. At the beginning of each transect the sled was placed in the water with the mouth of the net above the surface. The mouth was lowered into the water, and the sled was pushed along the transect. As the sled was pushed, the bottom of the net was slightly above the substrate

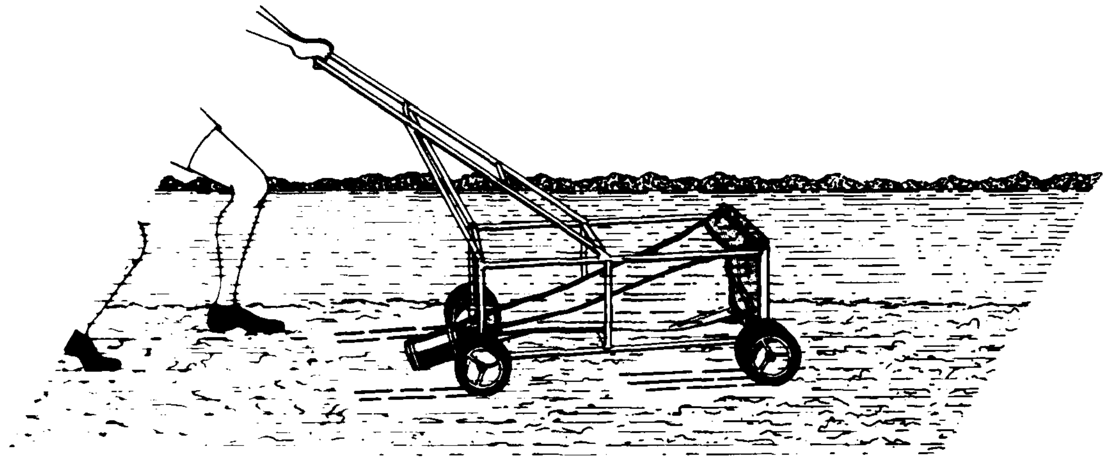


Figure 5. Push sled

surface and the top of the net was slightly below the water surface. At the end of the transect, the mouth was raised above the surface to stop filtering water. The contents were removed from the collection bucket and preserved in 10-percent buffered formalin.

Diaphragm pump

12. A Homelite Model 111DP3 diaphragm pump mounted in a 16-ft (4.9-m) johnboat was used to collect day and night samples from stations on dikes and revetments. Flexible polyvinyl chloride intake and discharge hoses of 7.62 cm diameter were attached to the pump. A person in the boat operated the pump and recorded data. A second person moved the opening of the intake hose over crevices between rocks along the sampling station. A third person held the boat away from the shore and moved the boat in pace with the person holding the intake hose (Figure 6). Each sample involved 5 min of pumping (approximately 1,514 *r* of water filtered). The discharge hose passed water into a 0.5-m-diam conical net (0.505-mm mesh) and collection bucket mounted on the side of the boat.

13. "Background" samples were desired for comparison between the dike/revetment samples and the components of the natural drift in the

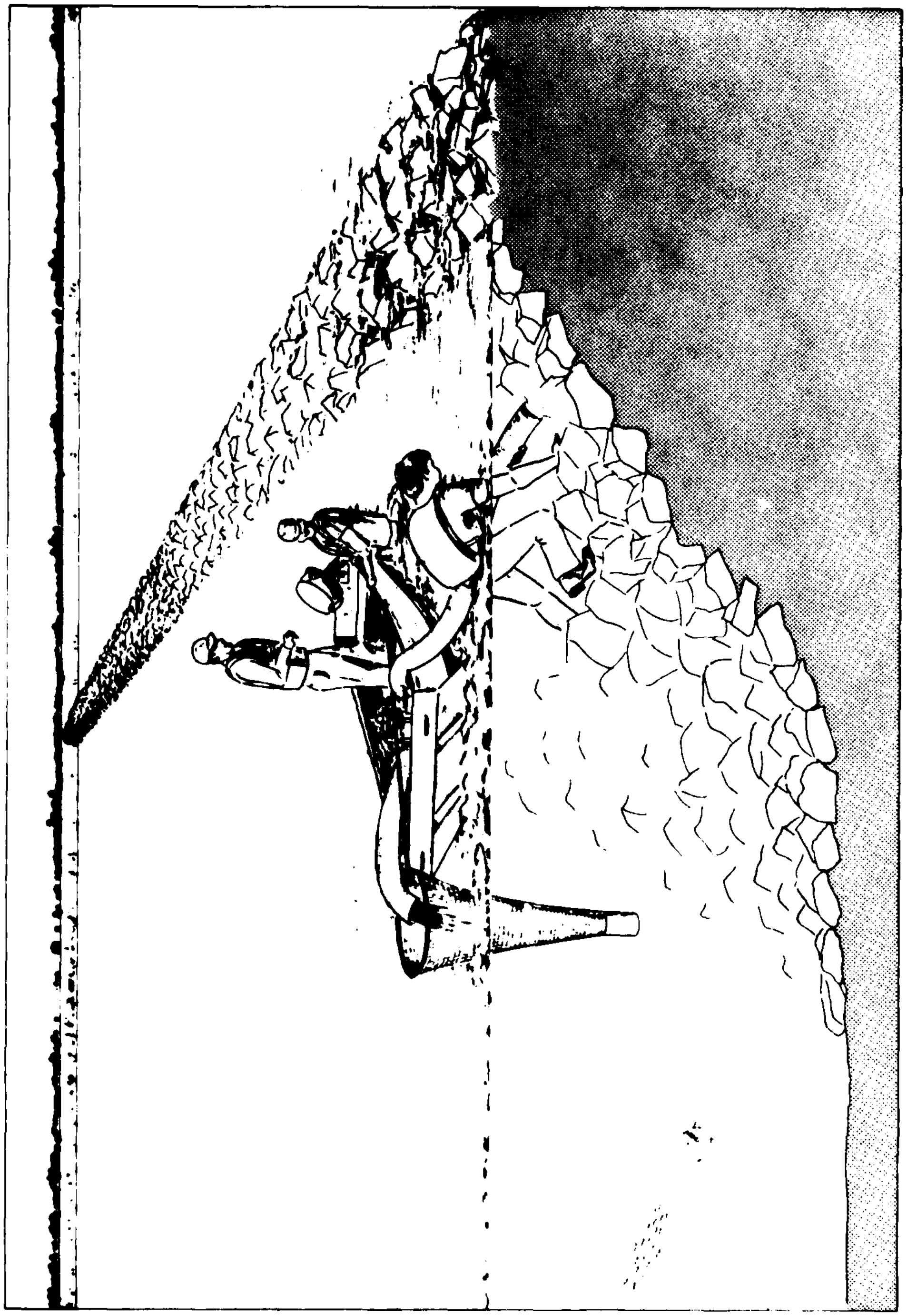


Figure 6. Diaphragm pump

river during the same time frame. Background samples collected along dike structures were obtained by holding the boat in a stationary position 25 m upstream and 25 m downstream of those stations sampled on the dikes. Background samples collected along revetted banks were collected by holding the boat in a stationary position approximately 5 m from the shoreline and 25 m upstream and 25 m downstream of those sections of revetment sampled.

Electroshocker

14. A boat equipped with electroshocking gear was anchored downstream of a dike or revetted bank, sampling close enough for the electrodes to touch the submerged rocks. Both day and night samples were obtained at each station (Figure 2). Samples were obtained simultaneously on the port and starboard sides of the boat using a 0.5-m-diam conical net (0.505-mm mesh) fitted on a yoke attached to an insulated handle (Figure 7). The nets were held 0.25 m below the water surface along the revetted bank and the dike. Each sampling period lasted 5 min.

15. At each station, background samples were obtained under control conditions (to estimate natural drift of macroinvertebrate larvae while the electroshocker was not activated) and during several levels of shocking (DC 120, 180, and 240 V; AC 100, 160, and 240 V) to determine the effect of an electrical field on the susceptibility of macroinvertebrates to being captured (i.e., obtain macroinvertebrates associated with crevices between, on, and behind rocks). Three people were required to obtain these samples: one each to manipulate the two nets and one person to operate the electroshocking equipment and record data.

ACM implants

16. Prior to a rise in river stage, entire ACM slabs were removed from revetment banks by cutting the wires that hold the individual slabs together. These slabs were then cut into blocks measuring 12 × 14 in. (approximately 30 × 36 cm) (Figure 8). The underlying substrate was then excavated to a depth of 12 in. (30 cm), and this substrate was placed in a perforated plastic pan (Figure 8). The blocks that had been

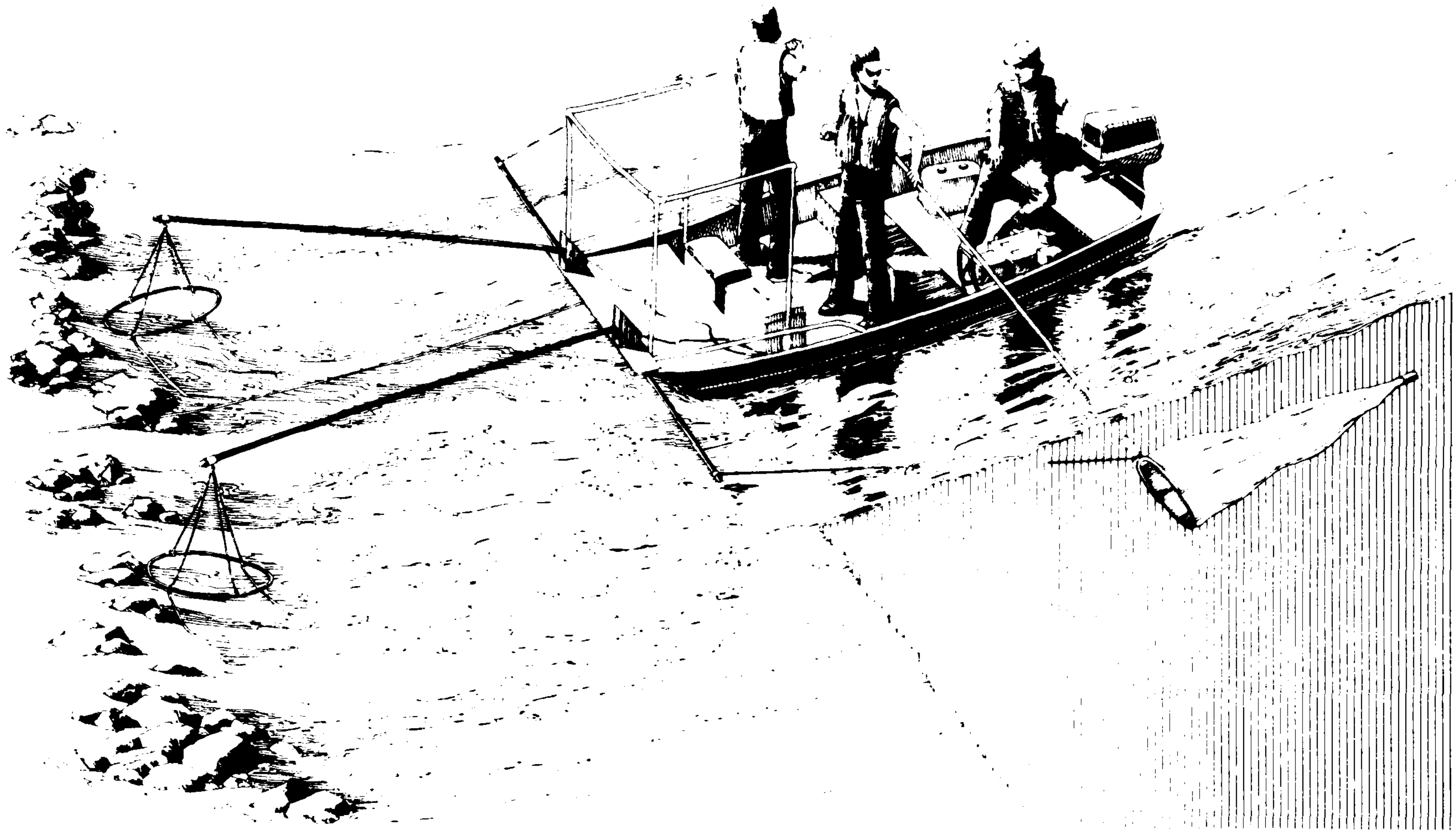


Figure 7. Electroshocking

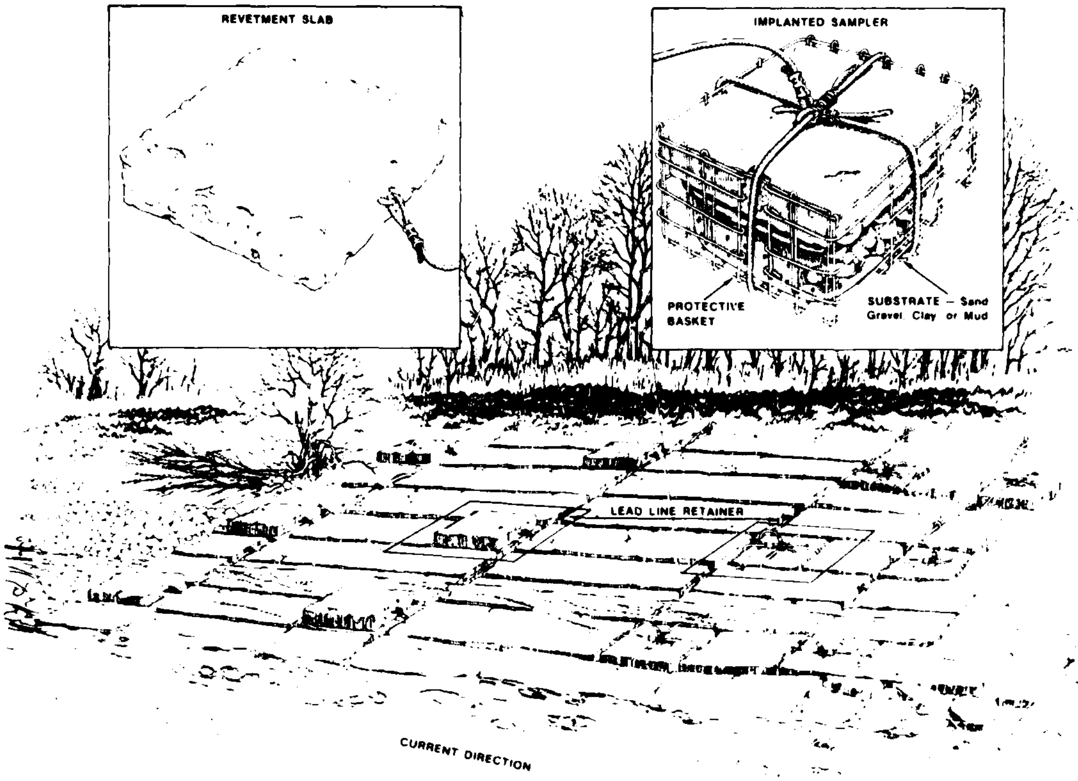


Figure 8. ACM slabs and implants

cut were then placed on top of the substrate which filled the plastic pan. This was then placed in a wire basket (mesh size 2 × 4 in. (5 × 10 cm)) (Figure 8) and placed in the hole that had been excavated. The sampler was tied in such a manner that, upon retrieval, the entire unit could be lifted from the water column. A wire cable (lead line) was attached to each sampler, extended up the revetment to the top bank (Figure 8), and was secured to a stationary object so that samplers could be retrieved during higher river stages.

17. Samplers were implanted at Marshall-Browns Point Revetment in January 1982 (Figure 1), and these became inundated shortly after placement. Samplers were retrieved in May 1982 by cutting the wire line from the top bank and attaching this line to a boom-mounted anchor windless in a boat positioned directly over the samplers. Samplers were

retrieved as fast as possible to reduce the number of organisms that might become dislodged during retrieval.

ACM slabs

18. Entire slabs of ACM were removed from a section of revetment near river mile 447 (Figure 1). Slabs were removed by wading to a depth of approximately 2 ft (0.6 m) and cutting the slabs free from adjacent slabs. The slabs were then removed from the water column and placed in galvanized tubs where the surfaces of each were brushed clean. The sample was placed in 10-percent buffered formalin.

ACM blocks

19. Entire ACM slabs were removed from a section of revetment and were cut into smaller blocks (12 × 15 in.) (approximately 30 × 38 cm). Eyebolts were then placed in each of the blocks (Figure 8). ACM block samplers were placed at three different locations during August 1983--at river miles 447, 445, and 440 (Figures 1 and 3). Samplers were deployed by attaching a wire cable to the eyebolt of the slab, wading to a depth of approximately 1 m, and placing the block sampler on the existing ACM. The opposite end of the lead line was then run up the revetted bank and anchored at the top bank.

20. The ACM block samplers were retrieved in October 1983, after approximately 2 months of inundation. River stage was closely monitored so that samples might be collected when they were inundated by no more than 0.7 to 1 m of water. The samplers were retrieved by following the wire cable from the top bank down to the samplers and picking them up by hand and placing them in galvanized tubs. A 0.25-mm-mesh drift net was held downstream and beneath the samplers as they were raised to capture any macroinvertebrates that might become dislodged. Blocks were brushed clean in the tubs, and the resultant sample plus anything caught in the drift net were preserved in 10-percent buffered formalin.

Modified Hess sampler

21. A conventional Hess sampler was modified (Figure 9) to accommodate its use on revetment structures. The sampler had a diameter of 13 in. (33.0 cm) and a height of 13.5 in. (34.3 cm). The foam rubber base was removed, and the base of the stainless steel cylinder was cut

off to leave approximately 4 cm below the catch net window. Polyurethane hosing (1.27 cm diameter) was used to replace the foam rubber seal that had been removed. Also, the relatively fixed catch-cup was replaced with a detachable catch-cup for ease of transferring the sample to a fixative.

22. The modified Hess sampler was used to collect samples from the revetment surface on 25 August at Marshall-Browns Point Revetment (Figure 1). The sampler was placed on the upper side of a revetment slab in approximately 0.5 m of water. That area of revetment which was encircled by the sampler was cleaned thoroughly with a stiff bristle brush as currents carried the freed materials into the catch-cup. Samples were removed from the catch-cup and preserved in 10-percent formalin.

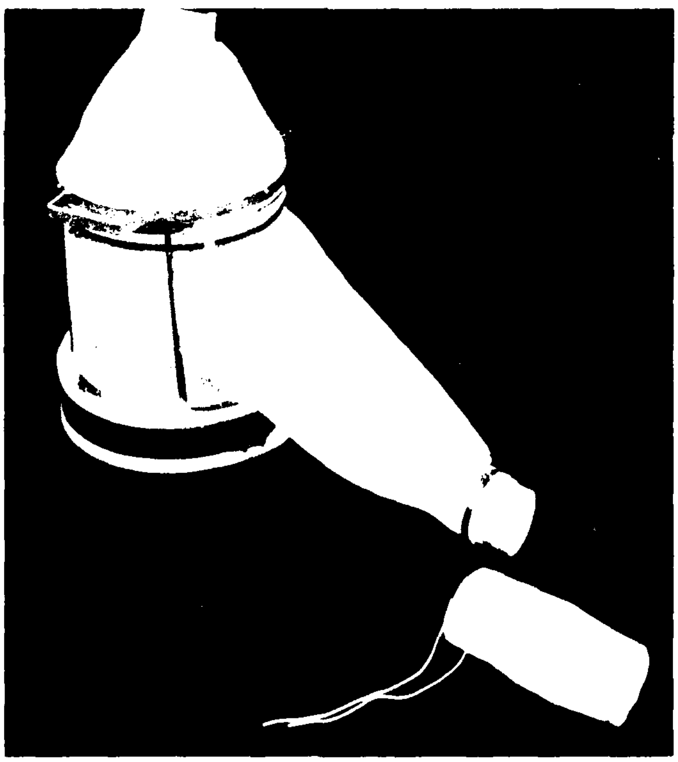


Figure 9. Modified Hess sampler

Data Analysis Procedure

23. Where possible, per-station abundance and diversity of macroinvertebrates were evaluated by analysis of variance (ANOVA) and Duncan's multiple range test using Statistical Analysis System software. The diaphragm pump and push sled data were evaluated for diel and monthly differences. The electroshocker data were evaluated for diel, habitat, and electrical current differences. Data from the circular rock basket implants, modified Hess sampler, ACM implants, ACM slabs, and rock samples were not analyzed statistically. The ACM block data were analyzed for habitat differences.

24. The usefulness of each gear was evaluated based upon the relative difficulty of using the gear to obtain the number and type of samples sought, the abundance and diversity of macroinvertebrates collected in each habitat where it was used, and the likelihood that the samples collected at each habitat and time were representative of what was to be expected (abundance and diversity) based on previous studies by WES and other investigators in the same or similar habitats.

PART II: RESULTS AND DISCUSSION

Circular Rock Basket Implants

25. Results obtained from the circular rock basket implants show this to be a potentially viable technique for sampling the stone riprap associated with dike and revetment structures. In May 1982, 129 macroinvertebrates (Table 1) representing 30 taxa were collected from the dike structures, and a total of 632 macroinvertebrates (Table 1) representing 43 taxa were collected from the revetment structure using this technique. The mean density for samples collected from the dike structures was 8.6 organisms/sample (Table 1) as compared to 79 organisms/sample collected from samples taken on the revetment structure. Field observations indicated that samplers collected from the dike structures were exposed to a greater degree of siltation compared to those samplers retrieved from the revetment.

26. Species composition was similar in both habitats; however, differences were noted in the relative abundance of the various groups of macroinvertebrates collected. Sprawling mayflies (Heptageniidae) and chironomid larvae (Chironomidae) were the dominant macroinvertebrate groups collected from the dike structures, representing 55 and 19 percent (Figure 10a), respectively, of the total numbers, whereas hydropsychid caddisflies (Hydropsychidae) and chironomid larvae (Chironomidae) comprised 49 and 17 percent (Figure 10a), respectively, of the total numbers in samples collected from the revetted bank. Certain macroinvertebrates more typical of lentic conditions and soft substrate, such as tubificid oligochaetes (Tubificidae), isopods (Isopoda), and burrowing mayflies (Ephemeridae) were collected but in relatively small numbers.

Advantages

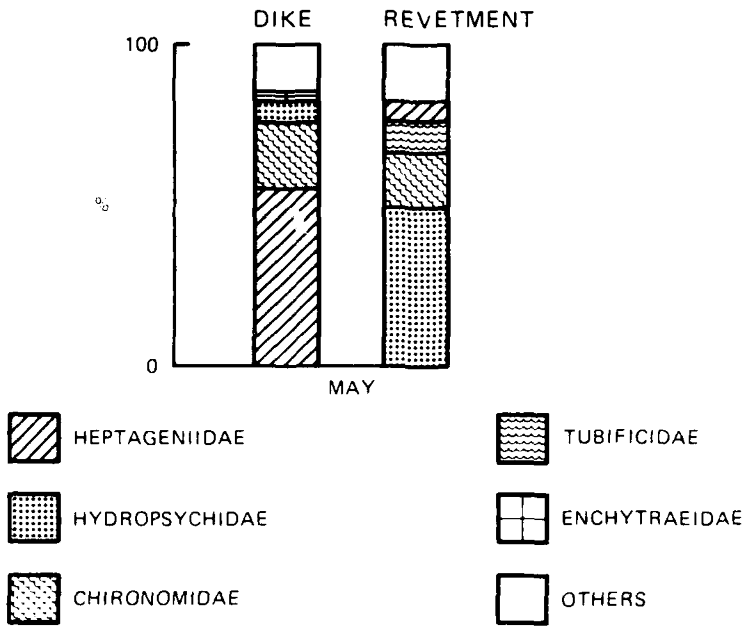
27. Circular rock basket implants are relatively easy to implant and remove, and can be retrieved regardless of river stage with little or no loss of organisms.

Table 1

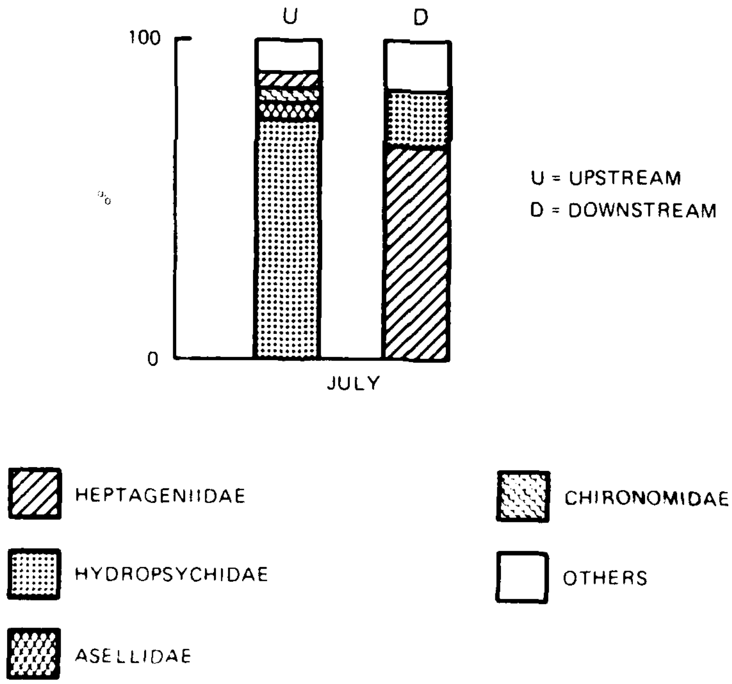
Macroinvertebrate Data Summary (By Date and Gear Type)

Gear	Sampling Location	Total No. Macro-invertebrates Collected		Mean Number of Organisms/Sample		No. Taxa Collected		Total No. Taxa Collected
		Night	Day	Night	Day	Night	Day	
Dike Habitat, May 1982								
Circular rock basket implant	Downstream	NS*	129	NS	8.6	NS	30	30
Diaphragm pump	Upstream	246	103	35.1	14.7	24	26	35
Diaphragm pump	Downstream	466	144	58.3	20.6	14	10	
Push sled	Pools	18	0	3.0	0	7	0	7
Revetment Habitat, May 1982								
Circular rock basket implant	Revetted bank	NS	632	NS	79	NS	43	43
Diaphragm pump	Revetted bank	11	11	1.6	1.6	8	10	14
Revetment Habitat, August 1982								
ACM slabs	River mile 447	NS	26,402	NS	8,800.6	NS	30	30
Revetment Habitat, October 1982								
ACM blocks	River mile 447	NS	69,702	NS	10,709.0/m^2	NS	51	51
ACM blocks	River mile 445	NS	2,040	NS	443.7/m^2	NS	39	39
ACM blocks	River mile 440	NS	876	NS	381.1/m^2	NS	30	30
Hess sampler	River mile 447	NS	2,704	NS	5,263.8/m^2	NS	21	21

* NS = not sampled.



a. Circular rock basket implants



b. Rock samples

Figure 10. Percent composition of dominant macroinvertebrate groups collected

Disadvantages

28. Circular rock basket implants are expensive to construct due to materials, welding and net construction, and final assembly labor. In addition, an extensive amount of sediment can collect around the rocks in the inner basket, reducing the surface area available for colonization by certain groups of macroinvertebrates. The circular rock basket implant may be better suited for use in areas with a reduced sediment load or fast current velocity so that deposition does not occur. A problem also exists with getting a good measure of surface area due to the roughness and irregular shape of stones used in this sampler.

Rock Samples

29. Data collected from rock samples taken from dike and revetment structures were not quantitative; however, consistent trends were apparent when comparisons were made regarding both overall density and numbers of taxa collected from each of the two habitat types (dike and revetment). In July 1982 a total of four organisms (Table 2) representing three taxa were collected from the revetment structure, as compared to 365 macroinvertebrates representing 16 taxa (Table 2) from the dike structure. The mean density for samples collected from the revetment structure was 1.3 organisms/sample as compared to 45.6 organisms/sample (Table 2) collected from the dike structure. Of particular interest are the consistent trends that were noted in comparisons made between the upstream and downstream faces of the dike structures. Many species were common to both the upstream and downstream face of the dikes but with different relative abundances. Hydropsychid caddisflies (Hydropsychidae) predominated on the upstream face, accounting for approximately 77 percent (Figure 10b) of the total numbers collected, while they were second in abundance on the downstream face of the dikes (16 percent). The sprawling mayflies (Heptageniidae) were the dominant group collected, accounting for approximately 67 percent of the total numbers collected from the downstream face of the dikes. Mean densities

Table 2

Macroinvertebrate Data Summary, July 1982

Gear	Sample Location	Total No. Macroin-vertebrates Collected		Mean Number of Organisms/Sample		No. Taxa Collected		Total No. Taxa Collected
		Night	Day	Night	Day	Night	Day	
	Dike Habitat							
Electroshocking (all voltages)	Downstream	355	55	39.4	6.1	19	11	24
Electroshocking (natural drifts)	Downstream	241	54	26.8	6.0	19	11	23
Push sled	Pools	463	81	51.4	9.0	12	12	18
Rock samples	Upstream	NS*	341	NS	42.6	NS	21	16
Rock samples	Downstream	NS	24	NS	3.0	NS	8	
Diaphragm pump	Upstream	NS	53	NS	13.3	NS	13	15
Diaphragm pump	Downstream	NS	31		7.8	NS	13	
	Revetment Habitat							
Electroshocking (all voltages)	Revetted bank	70	75	11.6	12.5	20	9	23
Electroshocking (natural drift)	Revetted bank	65	57	5.4	4.8	17	10	20
Diaphragm pump	Revetted bank	21	32	3.5	5.3	10	12	15
Rock samples	Revetted bank	NS	4	NS	1.3	NS	3	3

* NS = not sampled.

of total macroinvertebrates sampled from the dike structure were 42.6 organisms/sample for the upstream face and 3 organisms/sample for the downstream face.

Advantages

30. The sampling effort required for rock samples is minimal, and sampling is not biased by "gear effect."

Disadvantages

31. Sampling is entirely river stage dependent and, due to seasonal variations in river stage, comparisons regarding the macroinvertebrate fauna colonizing the dike structures cannot be made.

Push Sled

32. The push sled was used to collect drifting macroinvertebrates in dike pool habitats. A combined total (day and night) of 18 macroinvertebrates (Table 1) representing seven taxa were collected in May, as compared to 544 macroinvertebrates (Table 2) representing 18 taxa in the samples taken in July. Samples collected in May were dominated by chironomid larvae (Chironomidae), while those collected in July were dominated principally by *Macrobrachium ohione* (Palaemonidae) and *Taphromysis louisiane* (Mysidae), which, combined, accounted for approximately 56 percent (Figure 11) of the total numbers collected in samples taken during the day and <69 percent of the total numbers collected at night. Other taxa such as tubificid oligochaetes (Tubificidae), pelecypods, and burrowing mayflies (Ephemeridae), which are relatively uncommon in the seston and yet common to bottom substrates, were collected in fairly high numbers. This is attributed in part to the fact that, on occasion, the push sled would sink, thereby collecting organisms from the sediment.

33. Significant ($P < 0.05$) seasonal and diel differences were observed using this technique. Density estimates were higher in July as compared to May, as were the number of taxa collected. Significant diel trends were also observed during both sampling efforts, with the higher

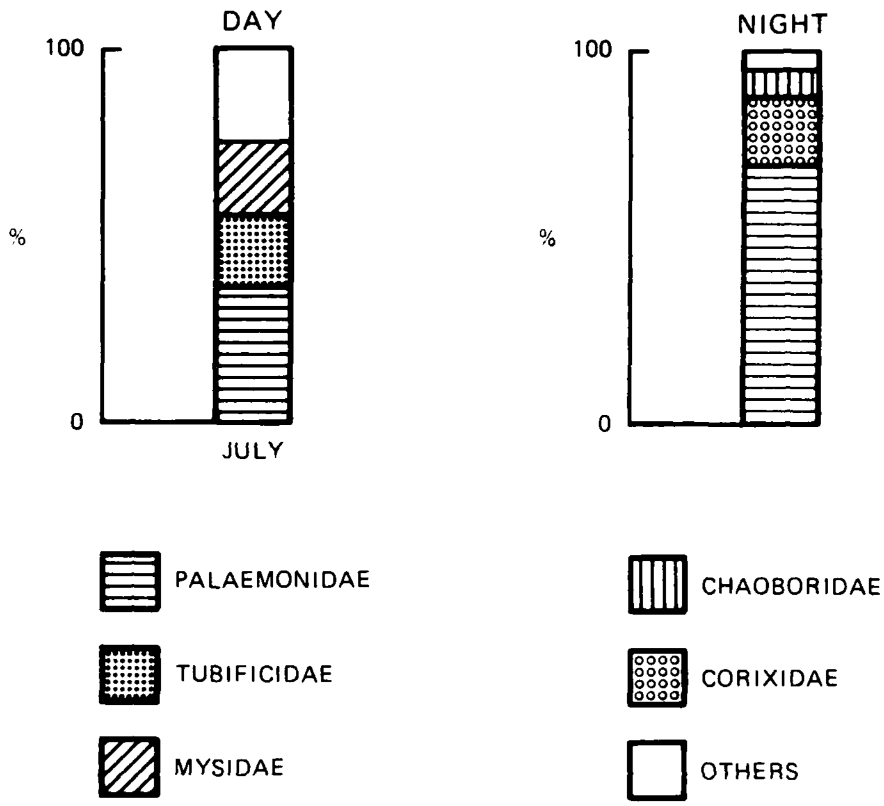


Figure 11. Percent composition of dominant macroinvertebrate groups collected with sled

densities and numbers of taxa collected during the night sampling efforts (Tables 1 and 2).

Advantages

34. The macroinvertebrate push sled sampler was simple to use due to its small size and relatively light weight. Samples were obtained easily and quickly. The sled performed well in shallow water inaccessible to even small boats and rolled smoothly over sand substrate, producing an even flow of water into the net.

Disadvantages

35. The push sled did not perform well on soft substrates (mud or silt); however, this might be overcome by the addition of extra wheels

that would provide more surface area and eliminate the sinking of the sampler into the substrate.

Diaphragm Pump

36. Samples collected from dike structures in both the May and July 1982 sampling efforts exhibited both higher numbers of taxa and higher numbers of macroinvertebrates as compared to samples collected from the revetted bank habitat. Overall, a total of 959 macroinvertebrates representing 35 taxa were collected from the dike structures in May (Table 1) as compared to 22 macroinvertebrates representing 14 taxa collected from the revetment structure. In July, a total of 84 macroinvertebrates representing 15 taxa were collected from the dike structures, while 53 macroinvertebrates representing 15 taxa were collected from the revetted bank. Two species, *Stenonema integrum* (Heptageniidae) and *Gammarus* sp. (Asellidae) were the dominant organisms collected from the dike structures during both day and night and May and July sampling efforts.

37. During the May daytime sampling effort these two species accounted for approximately 50 percent (Figure 12) of the total numbers collected on the upstream faces of the dikes and approximately 85 percent of the total on the downstream faces of the dikes. The same trend was apparent in samples collected at night in May, with these two species accounting for approximately 72 percent (Figure 12) of the total numbers on the upstream sides of the dikes and approximately 86 percent of the total numbers collected on the downstream faces of the dikes.

38. In July these two species accounted for approximately 72 percent (Figure 12) of the total numbers collected from the upstream faces of the dikes and 55 percent on the downstream faces. The river shrimp *Macrobrachium ohione* (Palaemonidae), tubificid oligochaetes (Tubificidae), isopods (Asellidae), and chironomid larvae (Chironomidae) were frequently collected but occurred in relatively low numbers. Species composition was similar on the revetted bank; however, total numbers collected were much smaller.

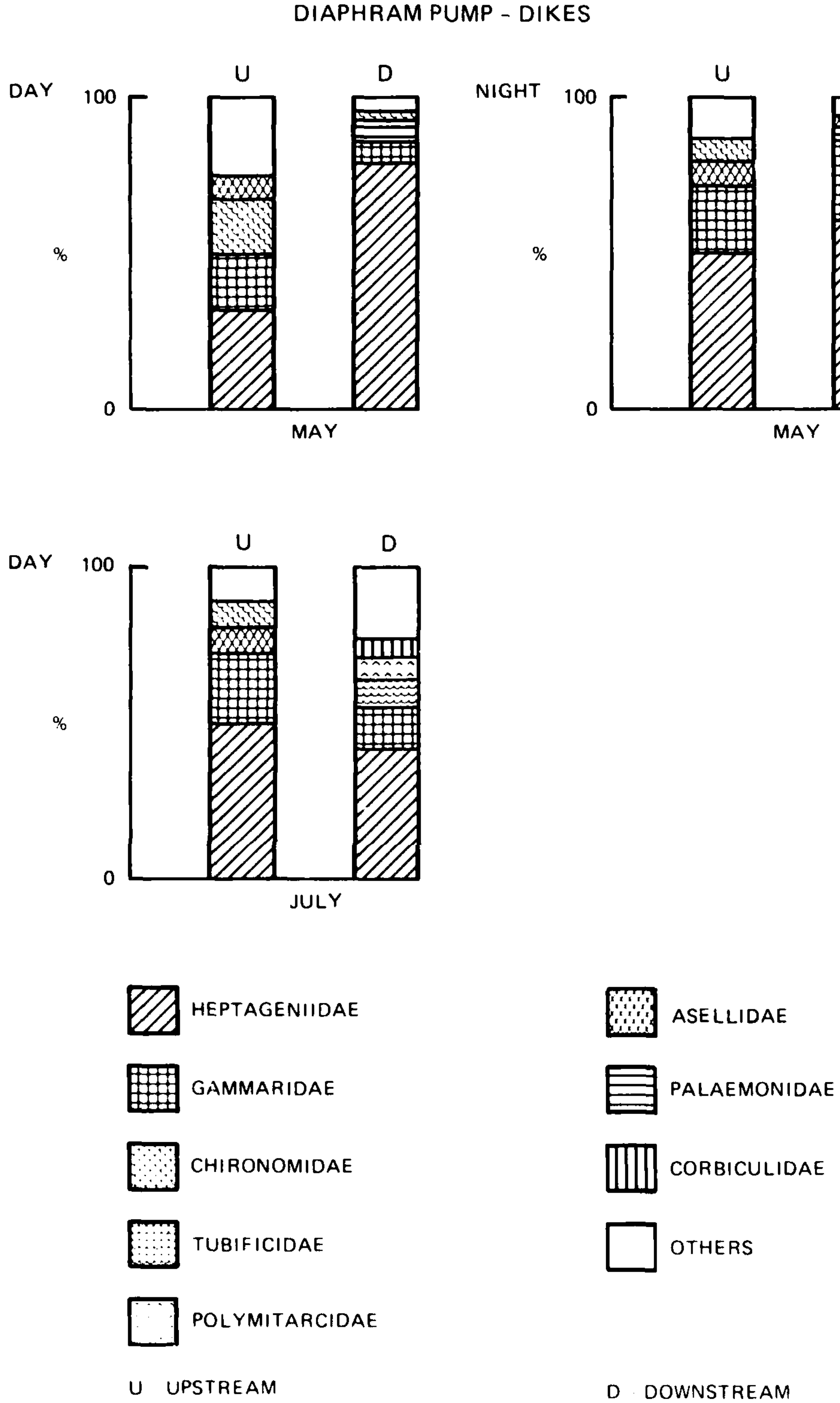


Figure 12. Percent composition of dominant macroinvertebrate groups collected from dike structures with diaphragm pump

39. Sample densities differed significantly ($P < 0.05$) on dike structures in comparisons made between monthly samples, with those samples collected in May showing the highest density estimates (Table 1). Significant ($P < 0.05$) differences were also noted in day versus night sampling (diel) in May, with those samples collected at night exhibiting the highest density estimates (Table 1). No diel comparisons could be made with samples collected in July due to equipment malfunction. No consistent diel trends were noted either for numbers of taxa or for numbers of macroinvertebrates collected from the revetment structure; however, slight seasonal trends in density estimates were apparent as total numbers of macroinvertebrates were higher in July as compared to May. Overall, both day and night samples collected from dikes and revetment in May and July displayed higher densities and numbers of taxa as compared to background samples collected 25 m away from each of the two habitats.

Advantages

40. Sampling with the diaphragm pump is fairly easy. This technique also offers the advantage of sampling the interstitial spaces between rocks, which cannot be done using certain of the other sampling techniques.

Disadvantages

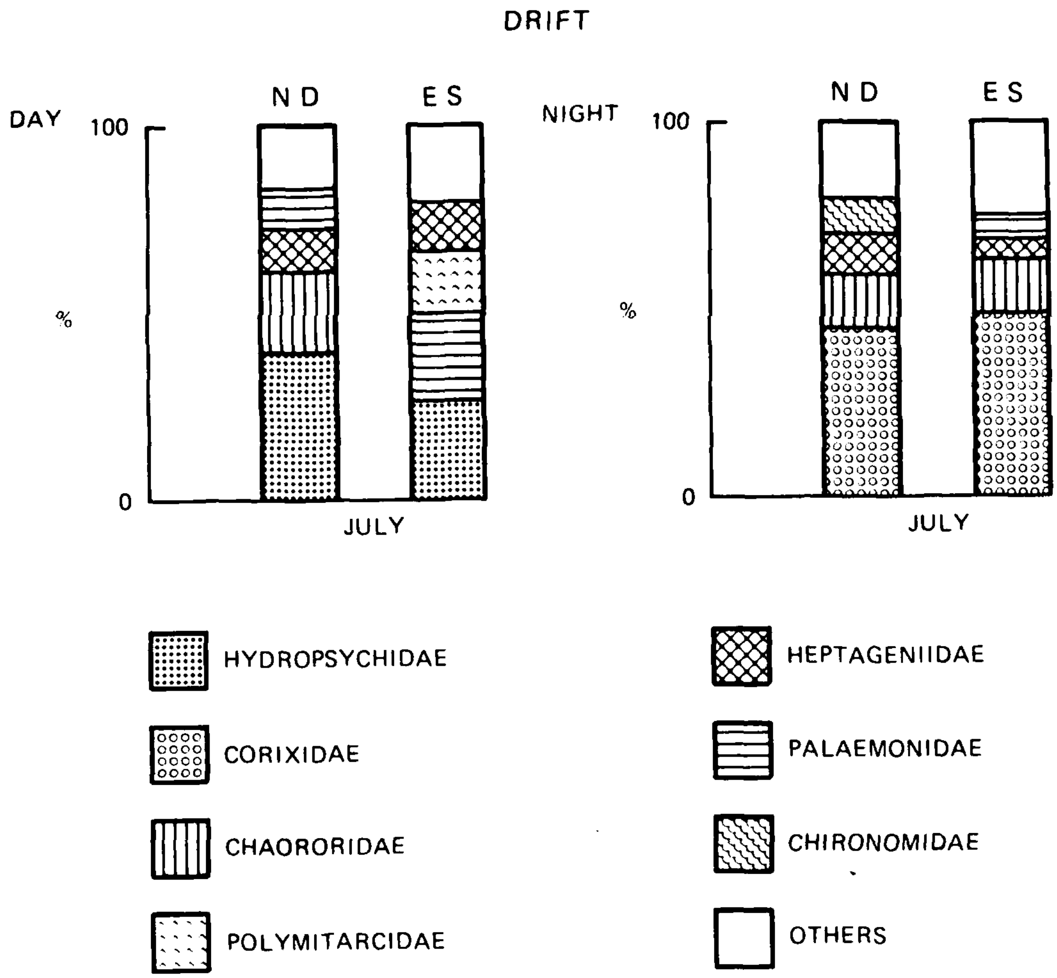
41. This sampling technique is entirely river stage dependent.

Electroshocker

42. Electroshocking does not appear to be a viable technique for sampling macroinvertebrates. Results of this study indicate that the organisms inhabiting dike and revetment structures do not respond to electrical stimuli in such a manner as to cause them to abandon the habitats investigated due to the presence of an electrical field. No differences ($P < 0.05$) were detected among the six voltage levels (both AC and DC) nor between electroshocking versus natural drift samples in density or number of taxa collected.

43. Natural drift and electroshocking samples collected from the dikes included a total of 11 taxa collected during the day and 19 taxa collected at night (Table 2). On the revetment structure, electroshocking sampled 9 taxa during the day and 20 taxa at night (Table 2) as opposed to natural drift samples which collected 10 taxa during the day and 17 taxa at night. Density estimates were in general higher for samples collected on the dike structure as compared to those samples collected on the revetted bank. Overall (electroshocking and natural drift), a total of 109 macroinvertebrates were collected from samples taken during the day and 596 macroinvertebrates were collected at night from the dike structures. In comparison, a total of 132 macroinvertebrates were collected in samples taken during the day and 135 macroinvertebrates were collected at night from the revetment structure (Table 2).

44. Taxa common to both electroshocking and natural drift samples on dike and revetment structures were the river shrimp *Macrobrachium ohione* (Palaemonidae), *Stenonema integrum* (Heptageneiidae), *Hydropsyche orris* (Hydropsychidae), *Chaoborus punctipennis* (Chaoboridae), and *Tortopus incertus* (Polymitarcidae). While these species were for the most part the dominant macroinvertebrates collected from the dike structures during the day, a shift in dominance was noted for those samples collected during the night. The Corixidae (Hemiptera), which were not collected in samples taken during the day, accounted for approximately 46 percent (Figure 13) of the total numbers in samples collected at night. Consistent diel trends were noted for samples collected from the dike structures, with higher densities and more taxa being collected during night sampling in both shock and natural drift samples (Table 2). There were no consistent differences in density estimates for day and night samples collected on the revetted bank; however, the number of taxa was considerably higher in samples collected at night (Table 2).



ND = NATURAL DRIFT ES = ELECTROSHOCK

Figure 13. Percent composition of dominant macroinvertebrate groups collected in electroshocking and natural drift samples

ACM Implants

45. Data collected from the ACM implants were not analyzed, as all samplers retrieved were covered by silt and sand. Only a few macroinvertebrates, primarily tubificid oligochaetes (Tubificidae), were collected using this technique.

ACM Slabs

46. In this study a total of 26,402 organisms representing 30 taxa were collected from ACM slabs, averaging 8,800.6 organisms/sample (Table 1) in August 1983. Although the macroinvertebrate assemblage was very diverse, one group, the Chironomidae, accounted for approximately 85.6 percent (Figure 14) of the total numbers collected, with one genus within the family, *Rheotanytarsus* sp., being by far the dominant species collected. Other taxa that were present in fairly high numbers were *Hydropsyche orris* and *Potomyia flava* (Hydropsychidae) and *Cynellus fraternus* and *Nerueclipsis crepuscularis* (Polycentropodidae). The mayfly *Stenonema integrum* (Heptegeniidae) was common to all samples but in relatively low numbers.

Advantages

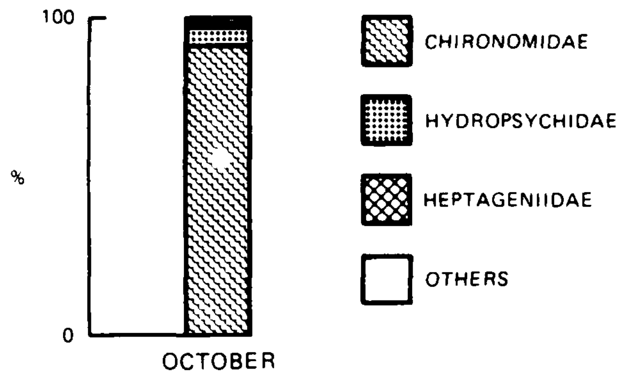
47. This technique can be employed at all river stages with the exception of extremely high flow (flood stage) and gives a very good estimate of the community composition of the revetment habitat at the time of sampling.

Disadvantages

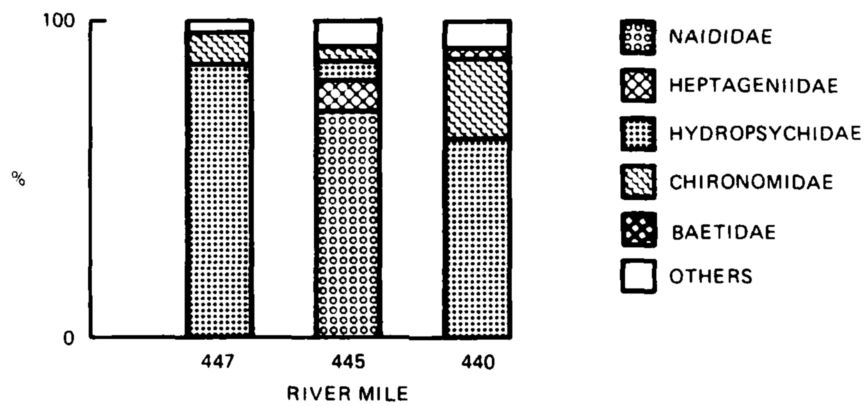
48. Fieldwork is very labor intensive. Also, samples collected using this technique are very large and may require subsampling and an inordinate amount of lab work.

ACM Blocks

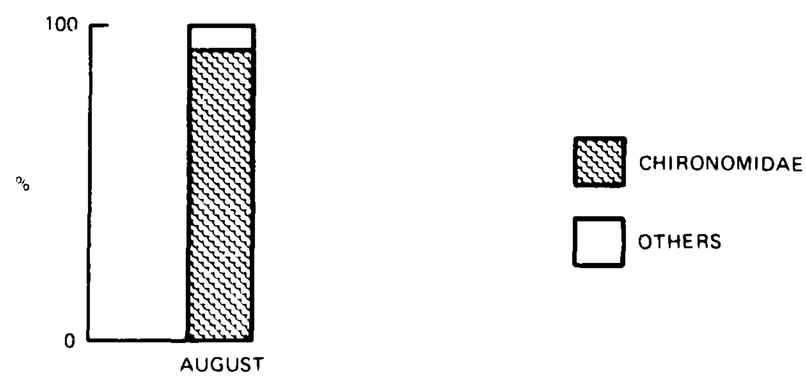
49. Articulated concrete mattress blocks appear to be an effective technique for sampling revetment structures. In October 1983, a combined total of 72,618 macroinvertebrates (Table 1) representing 68 taxa were collected using this technique. Of the three locations sampled (river miles 440, 445, and 447), those samples collected at river mile 447 exhibited higher density estimates compared to the other two sampling locations, while total number of species collected was relatively the same over all three sampling sites.



a. ACM slabs



b. ACM blocks



c. Modified Hess sampler

Figure 14. Percent composition of dominant macroinvertebrate groups collected with three techniques

50. A total of 69,702 macroinvertebrates (Table 1) representing 51 taxa were collected from samples taken at river mile 447. Field observations showed this reach of revetted bank to be fairly clean, although certain areas showed extensive accretion of sediments. Current velocities along this stretch of revetted bank ranged from 0 to 75 cm/sec. Hydropsychid caddisflies (Hydropsychidae) were the dominant macroinvertebrate group collected along this reach of revetment and accounted for approximately 85 percent (Figure 14) of the total number collected. Next in order of numerical abundance were the Chironomidae (Diptera), which represented 10 percent of the total number with two species, *Polpedilum illinoence* and *Rheotantarsus* sp. within the family Chironomidae, being present in very high numbers. Other groups common to all samples in relatively high numbers were the mayflies *Baetis* sp. (Baetidae) and *Stenonema* spp. (Heptageniidae). The mean density estimate for this stretch of revetment was 10,709 organisms/m^2 (Table 1).

51. A total of 2,040 macroinvertebrates (Table 1) representing 39 taxa were collected using ACM block samplers at river mile 445. Field observations along this stretch of revetted bank noted that nearly all samplers had some sand deposits and algal growth on their upper surface. Current velocities along this stretch of revetted bank ranged from 10 to 40 cm/sec. The worm *Nais pardalis* (Naididae) was the dominant macroinvertebrate, representing approximately 70 percent (Figure 14) of the total number collected. The mayflies *Stenonema* spp. (Heptageniidae) and the Chironomidae were next in order of numerical abundance, representing 8.4 percent and 5.3 percent, respectively, of the total sample numbers. The caddisflies *Hydropsyche orris* and *Potomyia flava* (Hydropsychidae) were common to samples collected, but in relatively low numbers. The mean density of macroinvertebrates collected along this stretch of revetted bank was 443.7 organisms/m^2 (Table 1).

52. A total of 876 organisms (Table 1) representing 30 taxa were collected at river mile 440. Most of the ACM slabs sampled had some silt accumulation on the top surface. Current velocities along this stretch of revetted bank ranged from 5 to 20 cm/sec. Caddisflies

(Hydropsychidae) were the dominant macroinvertebrate group collected, comprising approximately 62 percent (Figure 14) of the total number. Next in order of numerical abundance were the Chironomidae, representing approximately 25 percent of the total number. The mayflies *Stenonema* spp. were common but present in relatively small numbers. The mean density of macroinvertebrates collected along this stretch of revetted bank was 381.1 organisms/m^2 (Table 1).

Advantages

53. ACM block samplers are relatively easy to place and can be retrieved regardless of river stage.

Disadvantages

54. There is a potential for loss of organisms during retrieval of samplers.

Modified Hess Sampler

55. A total of 2,704 macroinvertebrates representing 21 taxa (Table 1) were collected using the modified Hess sampler in August 1983. Most areas of the revetment sampled with the Hess sampler were free of silt, although algae were present in some areas. Current velocities ranged from 30 to 80 cm/sec along this stretch of revetment. Representatives of the family Chironomidae (Diptera) were the dominant group of macroinvertebrates collected, representing approximately 94 percent of the total number collected. One species of chironomid larvae, *Rheotanytarsus* sp., accounted for 88 percent of all chironomids collected. Dipteran pupae and hydropsychid caddisflies were common to samples collected but in relatively low numbers. The mean density of macroinvertebrates collected by this method from revetment habitat was 5,263.8 organisms/m^2 (Table 1).

Advantages

56. The Hess sampler can be used to sample revetment surfaces regardless of river stage, and samples are very easy to obtain.

Disadvantages

57. Samples can be collected only from fairly shallow water (maximum depth approximately 3 ft (0.9 m)).

Discussion

58. Navigation structures such as dikes and revetments have become common in most navigable rivers within the United States. Many studies (Bingham, Cobb, and Magoun 1980; Cobb and Clark 1981; Miller 1981; Schramm and Pennington 1981; and Beckett et al. 1983) have addressed the potential biological impacts related to the placement of these structures on the Lower Mississippi River. The direct ecological contribution of these structures, however, has remained virtually unknown. To address this lack of information, several techniques have been utilized and evaluated in an attempt to define the most appropriate techniques for investigating the macroinvertebrate communities which colonize these habitats.

59. Macroinvertebrate community composition of dike structures on the Lower Mississippi River has been described as primarily lotic in nature (Mathis et al. 1981; Mathis, Bingham, and Sanders 1982). Macroinvertebrates that show a preference for hard substrates and erosional currents, such as the caddisflies *Hydropsyche orris* and *Potomyia flava* (Hydropsychidae), mayflies such as *Stenonema* spp. (Heptegeniidae), and certain chironomid larvae such as *Rheotanytarsus* sp. and *Polypedilum convictum*, usually dominate samples collected from the stone riprap used to construct the dike structures. Findings during this study showed similar results with regard to community composition as noted by Mathis, Bingham, and Sanders (1982) on dike structures on the Lower Mississippi River. Additional findings indicated the macroinvertebrate fauna colonizing dike structures was similar in composition to that of revetment structures. This fact was supported by most gear types used in this study, although certain of the gear types appeared to be more selective for particular macroinvertebrate groups.

60. Circular rock basket implants appear to be a viable technique for sampling dike and revetment structures where riprap is the principal construction material. Similar samplers have been used in studies of pollution (Higler 1984), macroinvertebrate colonization studies (Shaw and Minshall 1980), microdistribution studies of macroinvertebrates (Minshall and Minshall 1977), and vertical distribution (Morris and Brooker 1979). The circular rock basket was effective in documenting community composition of the dike and revetment structures. Differences were noted in the community composition of these two habitat types, with sprawling mayflies (Heptageniidae) being the dominant group collected on the dike structures and caddisflies (Hydropsychidae) being the dominant group collected on the revetment structures. This difference in relative dominance between the two habitat types can possibly be explained by the fact that all baskets were placed on the downstream side of the dikes and encountered turbulent currents, whereas those baskets placed on revetment structures were exposed to less turbulent current regimes. Hydropsychid caddisflies are net spinners (Wiggins 1977) and utilize the nets they construct for collection of food particles. Turbulent currents exhibited at the dike structures could disrupt this behavior and thereby explain the relatively low numbers of caddisflies collected in the dike structure habitat.

61. Rock samples were also effective in documenting macroinvertebrate community composition and allowed for the detection of relative differences in densities with regard to samples collected on the upstream versus downstream face of a dike structure. Overall density estimates were higher for those samples collected on the upstream face of the dike. Hydropsychid caddisflies were the dominant macroinvertebrate group collected on the upstream face of the dike structures, and sprawling mayflies (Heptageniidae) were the dominant group collected on the downstream face. The differences in both density estimates and relative dominance, with regard to upstream versus downstream face of the dike structures, may be explained in part by the turbulent conditions encountered on the downstream face compared to the less turbulent current regimes on the upstream face. Similar results were reported by

Mathis, Bingham, and Sanders (1982), who found that the lowest average density and lowest number of taxa occurred on the downstream face of the dike structures.

62. The push sled was very effective for sampling shallow-water sandbar habitats. Use of the sled revealed consistent diel and seasonal differences in the shallow-water macroinvertebrate drift. The night samples had a greater abundance of macroinvertebrate larvae, especially in July. Chironomid larvae were dominant in samples collected in May, whereas samples collected in July were dominated by river shrimp *Macrobrachium ohione* (Palaemonidae) and mysid shrimp *Taphromysis louisianae* (Mysidae).

63. Data collected using the diaphragm pump indicated similarities and differences in abundance and number of taxa between revetment and dike structure habitats. Samples collected along dike structures contained greater abundance and numbers of taxa than did samples collected along revetted banks in both May and July. Also, samples collected from dike structures using this technique showed both diel and seasonal trends, with more taxa present in samples collected at night versus samples collected during the day, and with higher density estimates recorded in May as compared to July. These trends were not evident in samples collected from the revetted bank habitat. This might be explained in part by the very low numbers collected from this habitat in both May and July. Two macroinvertebrate groups, heptageniid mayflies and amphipods (Gammaridae), were by far the dominant groups collected using this technique. Although heptageniid mayflies were common in collections using other techniques, gammarids were relatively uncommon. The fact that this technique was successful in collecting gammarid amphipods, as well as other groups common to slower current environments, may be attributed to its ability to sample interstitial spaces in the various habitats, which could not be done with the other techniques. The diaphragm pump was not very successful, however, in collecting macroinvertebrates such as hydropsychid caddisflies, which have hooklike features on their posteriors that enable them to cling to solid substrates.

64. Electroshocking on dike and revetment structures does not appear to be a viable sampling technique. An electrical field generated over and on the underlying substrate does not alter the abundance or numbers of taxa of macroinvertebrates collected. Numbers of taxa collected were usually comparable between any of the comparison series of control (natural drift) and electroshock samples.

65. Four methods were used exclusively on the revetted bank structures--the ACM implant sampler, ACM slabs, ACM blocks, and a modified Hess Sampler.

66. Due to the extensive siltation which occurred on the ACM implant sampler, no data were analyzed. Samplers yielded only a few organisms, primarily tubificid oligochaetes; however, it should be noted that the authors recognized many potential applications for this sampling technique as it is capable of sampling both the surface and underlying substrates. Care must be taken in selecting areas to place this type of sampler (i.e., high-energy environments with little or no sediment accretion), in order to obtain results that reflect conditions on a revetment not covered by a layer of sand or silt.

67. Results obtained from removing entire ACM slabs from revetted banks show this technique to be highly efficient. However, this sampling technique is very time consuming and labor intensive.

68. Articular concrete mattress blocks (small replicas of an entire ACM slab) were very effective in sampling macroinvertebrates at three different locations within the study area. Data collected showed location differences with regard to macroinvertebrate composition. Samples collected from two sites (river miles 440 and 447) were relatively silt free and were dominated by hydropsychid caddisflies; samples collected at the third site (river mile 445), which had a fine layer of silt over the majority of samplers, were dominated by *Nais pardalis* (Naididae). This macroinvertebrate is common in areas in which fine silt is the predominant substrate (Fomenko 1972). Location differences were also noted with regard to sample densities, with the site located farthest upstream (river mile 447) having consistently higher density estimates. This may be due in part to the conditions that existed at

this site (clean substrate and moderate current velocities), both of which made this reach of river favorable habitat for the dominant macroinvertebrate group collected, hydroysychid caddisflies.

69. Results obtained with the modified Hess sampler indicated that it was a valid technique for sampling the surface of revetment structures. Samples were collected in shallow water so that the area of revetment sampled could be seen to be devoid of organisms upon completion of sampling, thereby yielding a very representative sample. Areas sampled using the Hess sampler revealed the surface of these structures possessed a macroinvertebrate community comprised almost totally of members of the family Chironomidae, primarily *Rheotanytarsus* sp. This chironomid is common to lotic waters (Merritt and Cummins 1978) and was found by Mathis et al. (1981) to be a codominant species in samples collected from dike structures on the Lower Mississippi River.

PART III: CONCLUSIONS AND RECOMMENDATIONS

Conclusions

70. All gears evaluated, with the exception of the electroshocker, were successful to some degree in sampling the macroinvertebrate fauna which colonized the dike and revetment structures in the areas investigated.

71. The diaphragm pump is effective in sampling the macroinvertebrate fauna that colonized the dike structures and is effective in detecting diel and location (upstream versus downstream) differences in macroinvertebrate community composition. This technique does not appear to be effective in sampling revetment structures, however. This technique is totally river stage dependent and could not be used to detect seasonal changes in the communities which inhabit dike structures.

72. Both circular basket implants and rocks used to sample the dike and revetment structures are efficient techniques for sampling these habitats. Rock sampling can detect location differences (upstream versus downstream); however, it is a totally river stage-dependent technique whereas circular basket implants have the advantage of being retrieved regardless of river stage. One disadvantage of using this technique is that only a rough approximation of the stone's surface area can be ascertained, thereby making the data collected only semiquantitative.

73. The push sled is an effective technique for sampling shallow-water sandbar habitats. Both diel and seasonal differences in macroinvertebrate drift can be detected.

74. While the data collected using the revetment implants were not analyzed because all of the samplers were covered with sand and contained only a few organisms, this technique does show promise as it can serve two functions: sampling the revetment material, while at the same time sampling the substrate that is covered by the revetment. This technique is labor intensive. Therefore, in selecting sampling sites, one should avoid areas of sediment accretion.

75. The articulated concrete mattress slabs and blocks and the modified Hess sampler were all effective in sampling the revetment structures. Removal of entire ACM slabs is very labor intensive, whereas sampling with the ACM blocks and the Hess sampler can be accomplished with relative ease.

Recommendations

76. All of the techniques evaluated, with the exception of electroshocking, can be applied in macroinvertebrate studies whenever the habitat appropriate to each is to be sampled. Study design should incorporate the appropriate techniques for documenting standing crop estimates and diel and seasonal aspects of macroinvertabrate abundance and diversity, as well as other possible applications.

77. Efforts should be continued to refine the sampling techniques associated with the gears tested in this study. Additional gears should be developed and tested to sample other habitats of interest in Corps of Engineer macroinvertebrate investigations. If these additional gears can be proven reliable, they should be incorporated into an array of gears utilized in a multihabitat sampling program. This will enhance the probability of obtaining a clearer understanding of each habitat's contribution to the overall macroinvertebrate community of a river.

REFERENCES

Beckett, D. C., Bingham, C. R., Sanders, L. G., Mathis, D. B., and McLemore, E. M. 1983. "Benthic Macroinvertebrates of Selected Aquatic Habitats of the Lower Mississippi River; Final Report," Technical Report E-83-10, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Bingham, C. R., Cobb, S. P., and Magoun, A. D. 1980. "Aquatic Habitat Studies on the Lower Mississippi River, River Mile 480 to 530; Report 4, Diel Periodicity of Benthic Macroinvertebrate Drift," Miscellaneous Paper E-80-1, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Cobb, S. P., and Clark, J. R. 1981. "Aquatic Habitat Studies on the Lower Mississippi River; Report 2, Aquatic Habitat Mapping," Miscellaneous Paper E-80-1, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Fomenko, N. V. 1972. "Ecological Groups of Oligochaeta Worms in the Dnieper Basin," Aquatic Oligochaeta Worms, G. M. Belyaev et al., eds., pp 105-118 (English translation available as TT 75-52064, National Technical Information Service, Springfield, Va.).

Higler, L. W. G. 1984. "Reactions of Some Caddis Larvae (Trichoptera) to Different Types of Substrate in an Experiment Stream," Freshwater Biology, Vol 5, pp 151-158.

Mathis, D. B., Bingham, C. R., and Sanders, L. G. 1982. "Assessment of Implanted Substrate Samplers for Macroinvertebrates Inhabiting Stone Dikes of the Lower Mississippi River," Miscellaneous Paper E-82-1, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Mathis, D. B., Cobb, S. P., Sanders, L. G., Magoun, A. D., and Bingham, C. R. 1981. "Aquatic Habitat Studies on the Lower Mississippi River, River Mile 480 to 530; Report 3, Benthic Macroinvertebrate Studies--Pilot Report," Miscellaneous Paper E-80-1, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Merritt, R. W., and Cummins, K. W., eds. 1978. An Introduction to the Aquatic Insects of North America, Kendall/Hunt Publishing Company, Dubuque, Iowa.

Miller, A. C. 1981. "Aquatic Habitat Studies on the Lower Mississippi River, River Mile 480 to 530; Report 1, Introduction," Miscellaneous Paper E-80-1, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Minshall, G. W., and Minshall, J. N. 1977. "Microdistribution of Benthic Invertebrates in a Rocky Mountain (U.S.A.) Stream," Hydrobiologia, Vol 553, pp 231-249.

Morris, D. L., and Brooker, M. P. 1979. "The Vertical Distribution of Macroinvertebrates in the Substratum of the Upper Reaches of the River Wye, Wales," Freshwater Biology, Vol 9, pp 573-583.

Schramm, H. L., Jr., and Pennington, C. H. 1981. "Aquatic Habitat Studies on the Lower Mississippi River, River Mile 480 to 530; Report 6, Larval Fish Studies--Pilot Report," Miscellaneous Paper E-80-1, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Shaw, D. W., and Minshall, G. W. 1980. "Colonization of an Introduced Substrate by Stream Macroinvertebrates," Oikos, Vol 34, pp 259-271.

Wiggins, G. B. 1977. "Larvae of the North American Caddisfly Genera (Tricoptera)," University of Toronto Press Publishers, Toronto, Canada.

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